

## Chapter 5

# Strategic and Tactical Planning for Managing National Park Resources

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**Abstract:** Each National Park Service unit in the United States produces a resource management plan (RMP) every four years or less. These plans constitute a strategic agenda for a park. Later, tactical plans commit budgets and personnel to specific projects over the planning horizon. Yet, neither planning stage incorporates much quantitative and analytical rigor and is devoid of formal decision-making tools. The analytic hierarchy process (AHP) offers a structure for multi-objective decision making so that decision makers' preferences can be formally accounted for. Preferences for each RMP project, resulting from an AHP exercise, can be used as priorities in an overall RMP. We conducted an exercise on the Olympic National Park (NP) in Washington, selecting eight projects as typical of those considered in RMPs. Five members of the park staff used the AHP to prioritise the eight projects with respect to implicit management objectives. By altering management priorities for the park, three different scenarios were generated. All three contained some similarities in rankings for the eight projects, as well as some differences. Mathematical allocations of money and people differed among these scenarios and differed substantially from what the actual 1990 RMP contains.

## 1. INTRODUCTION

Resource managers in U.S. national parks must protect a wide array of natural resources, including measurable commodities, aesthetic values, and

ecosystem processes (Hinds 1984; Fox *et al.* 1987; Silsbee and Peterson 1991, 1993). Legal and political factors are often at least as important as biological and sociological factors in the development of long-term management plans. Decisions are commonly made in the absence of sufficient technical data or background information. This necessitates the use of expert judgement to evaluate the relative merit of proposed elements of a management plan and to plan for expenditures of time and money.

The selection of resource management activities in national parks is largely driven by how well any activity satisfies overall park management objectives. Projects are combined into a cohesive program to meet large-scale objectives, such as, inventory and monitoring of park resources. In contrast to traditional timber/economic models—e.g., Timber RAM (Navon 1971), MUSYC (Johnson and Jones 1979), and FORPLAN Versions 1 and 2 (Johnson 1986, Johnson *et al.* 1986)—of resource valuation and harvesting, resource management activities in national parks generally are not mutually exclusive and do not necessarily focus on particular tracts of land, e.g. forest stands.

The analytic hierarchy process (AHP) (Saaty 1980) can be applied to resource management decision making to prioritise objectives and alternatives for multi-criteria decisions (Schmoldt *et al.* 1994). This constitutes a *strategic* plan for what park managers would like to accomplish. Such an approach fails, however, to capture some realities, such as multi-year planning and partial allocation that are common in *tactical* planning problems. Therefore, straightforward analytical approaches are needed to allow resource managers to implement management strategies in an optimal manner (e.g., Kangas 1994).

In this paper, we direct our analytical focus on a list of projects included in the current resource management plan (RMP) of a large national park. Specifically, we (1) report on an application of the AHP to prioritise projects in the RMP for Olympic National Park (NP), and (2) compare project priorities that are based on different park management objectives, using Olympic NP as a case study.

## 2. RESOURCE MANAGEMENT PLANNING

RMPs are required for all National Park Service units in the United States. A standard written format, including budget information, is prescribed and RMPs are reviewed at least every four years. The existing planning process in most national parks is not rigorously structured. The management staff compiles a wide range of topics, discusses them, prioritises them, and develops an RMP with little analysis and without

formal decision-making tools. The result is a large and rather cumbersome document, and one that is difficult to justify to others and to modify, as needs change.

As a comprehensive summary of an ideal management strategy, the RMP is a valuable information source, but it is also a source of frustration for park personnel. There is nearly always a huge gap between the management programs described in the RMP and the actual programs that are constrained by budget and personnel limitations. Park managers see many critical needs for information, but they also realise that many of these needs will never be filled. Consequently, they must continually make decisions in the absence of adequate data. They also must choose between an extensive program (many projects at a low level of detail) and an intensive program (a few projects at a high level of detail). Finally, they know that political and operational constraints may override decisions based on scientific information and resource management expertise.

Allocating funds among different resource areas within a national park is a difficult process because of the wide range of resources, personnel, and issues involved. Nevertheless, parks currently have no formal process for prioritising among, and allocating budgets to, projects. The two-step process of prioritisation and allocation presented below introduces analytical rigor into resource management planning. It removes some of the mystery from decision making and allows plans to be re-examined and modified more easily.

### **3. PRIORITIZING PROJECTS USING THE AHP**

#### **3.1 An Overview of the AHP**

Many decision-making situations involve preferential selection among alternative items, events, or courses of action. When the selection criterion is “least cost,” the measurement scale is obvious and choosing becomes easy. In most real-world situations, however, there is not a single scale for measuring all competing alternatives. More often, there are several scales that must be used and often those scales are related to one another in fairly complex ways.

The AHP (Saaty 1980) helps to structure a problem into a hierarchy consisting of a goal and subordinate features. Subordinate levels of the hierarchy, may include: objectives, scenarios, events, actions, outcomes, and alternatives. Alternatives to be compared—in our case RMP projects—appear at the lowest level of the hierarchy.

### 3.2 Prioritising Projects in Olympic NP

We used the AHP in co-operation with five Olympic NP staff members to prioritise eight projects (Table 1) out of 147 in the 1990 RMP. The park staff contained highly experienced resource managers with scientific expertise in a wide range of natural-resource disciplines, including vegetation, wildlife, fisheries, and geospatial applications. Using a software implementation of the AHP, pairwise comparisons and project ratings within the AHP were developed interactively by projecting from a computer display directly onto an overhead screen so everyone could discuss the same topic simultaneously. All subjective judgements were reached by consensus of the resource management team through group discussion. In circumstances where consensus cannot be reached easily, separate judgements can be combined by using a geometric average (Schmoldt and Peterson 2000). The following eight projects were selected.

- *Monitor ambient air quality*—Olympic NP is known for its pristine air quality relative to most of the rest of the continental United States. Ambient air is monitored for sulphur dioxide, ozone, total suspended particulates, and visibility.
- *Monitor avalanches*—Subalpine slopes are subject to avalanche hazard in winter, creating problems on developed areas, roads, and ski trails. Avalanche forecasting is critical for visitor safety.
- *Monitor water quality*—Basic physical, chemical, and biological data are needed for water resources throughout the park in order to identify potential changes caused by acidic deposition and human activity.
- *Study and monitor plant communities affected by mountain goats*—Exotic mountain goats potentially threaten plant communities, including some endemic species. Long-term studies are needed to determine if the goats are impacting the growth and distribution of vegetation in alpine and subalpine areas.
- *Conduct studies or management programs for fish or wildlife species of special concern*—There are several threatened, endangered, or sensitive animals in the park, including the northern spotted owl. Populations must be studied to determine their status, and appropriate management actions should be taken if necessary.
- *Inventory and monitor selected anadromous fish stocks that are subject to harvest*—Many fish stocks in the park are managed co-operatively with other agencies and Native Americans. More information is needed on size and distribution of anadromous fish in the park, especially for stocks that have been reduced by harvest and habitat loss.

- *Study and monitor the Elwha watershed*—Two dams on the Elwha River have dramatically changed the aquatic and terrestrial ecosystems in this area. Proposals to remove these dams dictate the need for data on the impact of the presence and subsequent removal of the dams on physical and biological characteristics of the watershed.
- *Conduct an integrated pest management (IPM) program*—Control and eradication of native and non-native species defined as “pests” (wood-rot fungi, carpenter ants, rodents, etc.) are necessary in some developed areas of the park. The use of pesticides and other methods must be monitored and managed responsibly.

Table 1. Priority ratings and rankings for each project under different management objectives.

Project	Objective importance assigned by park staff		All objectives ranked equally		"Management decision making" has highest priority		Actual funding level in the 1990 RMP implicitly determines rankings	
	P <sup>a</sup>	R <sup>b</sup>	P	R	P	R	P	R
Air quality	.137	5	.130	6	.099	7	--	3
Avalanche monitoring	.069	8	.057	8	.111	6	--	2
Water quality	.140	4	.146	3	.122	5	--	5
Goat impacts	.141	3	.135	5	.179	1	--	1
Sensitive wildlife	.143	2	.149	2	.134	4	--	5
Anadromous fish	.128	6	.143	4	.145	3	--	4
Elwha watershed	.148	1	.163	1	.168	2	--	5
IPM program	.095	7	.077	7	.042	8	--	5

<sup>a</sup> Priority value

<sup>b</sup> Ranking

In addition to rating individual projects with respect to each objective and sub-objective, the Olympic NP team developed relative weights for the objectives themselves (Figure 1). Two hypothetical scenarios of objective importance were evaluated for comparison with results from staff-assigned objective priorities. In the first, all objectives were ranked equally—each had the same priority value (Figure 2). For the second scenario, each had a priority value of zero, except for “support management decision making,” which had a value of one (Figure 3). For both of these scenarios, the rating scores generated by the park staff for each of the projects across all criteria are the same as above. Different emphases on park management objectives, however, distinguish these scenarios from the original one. These two park

management alternatives were chosen because they represent reasonable competing policies for managing park resources.

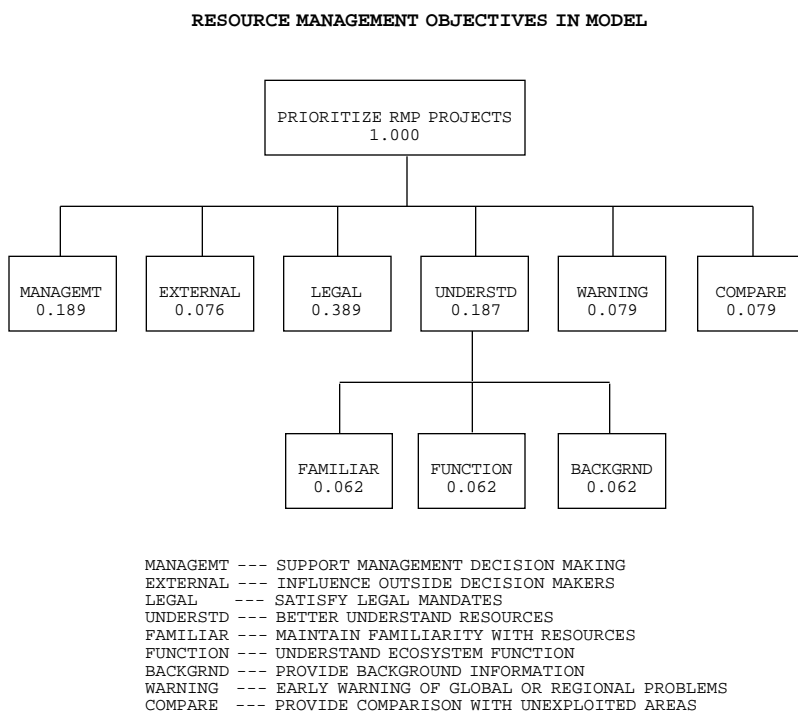


Figure 1. Objectives selected and ranked by park resource management staff are displayed in this hierarchy. Numbers associated with each objective are the global priority values that indicate the importance of each objective for ranking resource management projects

To compare these exercises using the AHP with some real-world results, actual allocation of resources to these eight projects in the 1990 RMP was also used to prioritise them *implicitly* (Table 1). Projects were prioritised based on each project's ratio of allocated to requested expenditures in the actual 1990 RMP. Four unfunded projects out of eight from the 1990 RMP were given an arbitrary ranking of 5 to indicate that they have a lower priority than those ranked 1-4, but otherwise are indistinguishable in rank. We assume here that rankings implied from expenditures provides some insight into implicit priorities by the 1990 RMP decision makers for these projects, i.e. high priority projects would receive a higher percentage of requested expenditures. An exception to this assumption about the expenditure-priority relationship is the avalanche monitoring project; its

funding is mandated because it is part of an extensive effort by multiple land management jurisdictions and is relatively inexpensive to implement.

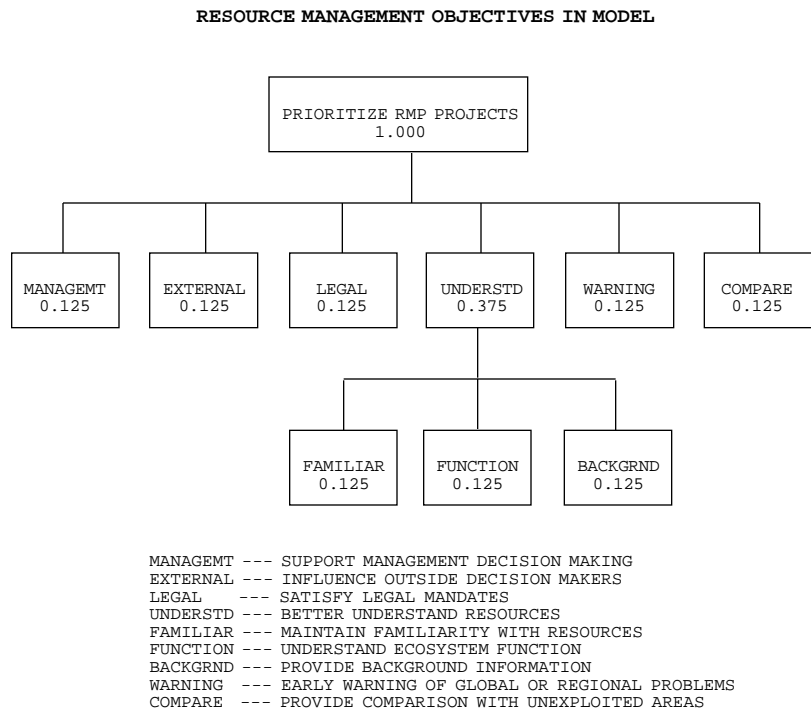


Figure 2. All objectives are ranked equally important in this hierarchy. Numbers associated with each objective are the global priority values indicating each objective’s importance for ranking resource management projects.

3.3 The Specific Formulation

Because our decision variables  $X_{ijk}$  (3.1) are two different types of entities, budget (dollars) and full-time equivalent personnel positions (FTE’s), we need some way to put them on the same scale. The conversion factor  $c_i$  performs this equilibration of dimensional units. We arbitrarily decided to convert FTE units to budget units; but, without any change in the final solutions, we could have converted budget units to FTE units instead. We then reasoned that the actual allocation of dollars and person-years in the 1990 RMP for these eight projects could be used as a ratio to equate expenditures of budget units and FTE units—an implicit valuation function for budget and FTE’s in *this* park and at *this* time. Of the eight projects considered in our example, only four received allocations, which amounted

to \$142.6K and 5.2 person-years; therefore, each person-year is equivalent to \$27.4K. Then, because dollars remain unconverted,  $c_1 = 1$ .

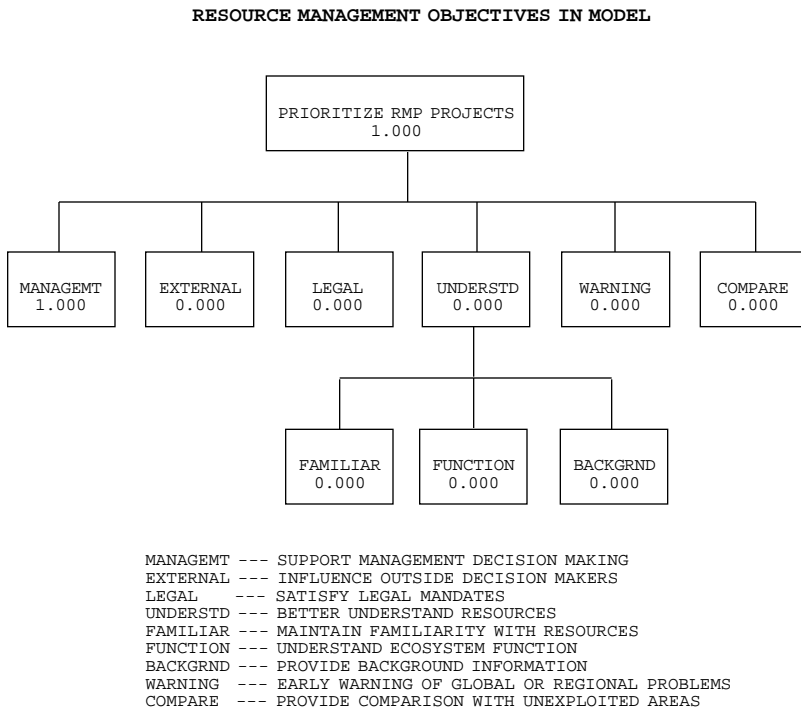


Figure 3. Support of management decision making is the only objective in this hierarchy. Numbers associated with each objective are the global priority values indicating the importance of each objective for ranking resource management projects

Our case study example deals with only a small number of projects. The actual 1990 RMP for the park contained 147 projects that were considered for inclusion in the park's management plan. In addition to the constraints listed below (3.2-3.3), several others were added to make the eight-project exercise comparable to the 147-project reality of the actual 1990 RMP (Peterson *et al.* 1994).

Requested expenditures  $R_{ij}$  (3.2) and total allocation figures  $T_j$  (3.3) were taken directly from the 1990 RMP. Actual allocations for budget and FTE's for all eight projects were assigned to  $T_1$  and  $T_2$ . Several additional constraints were included to mirror more closely the implicit allocation methods used in the actual RMP. First, actual 1990 RMP allocations exhibited a nonincreasing flow of expenditures over the four-year planning period. Uncertain future budgets and the problems associated with overly



optimistic expectations are a likely reason for this type of planning. This nonincreasing characteristic was reflected in each individual project as well as in the total program. In fact, for each funded project in the 1990 RMP, either all expenditures occurred in the first year or there was an even flow of expenditures over the four years. Because our linear programming software does not allow “exclusive-or” constraints, we used a straightforward nonincreasing inequality. The following set of constraints (3.4) was added to our formulation to reflect these apparent long-term planning realities. An additional set of constraints like those in (3.4), except with “=” replacing “ $\leq$ ”, was used for strict even-flow expenditures for “avalanche monitoring.”

Objective function:

$$\text{Max } Z = \sum_i \sum_j \sum_k p_i c_j X_{ijk} \quad (3.1)$$

where,

$p_i$  is the priority of project  $i$

$c_j$  is the conversion factor for expenditure type  $j$

$X_{ijk}$  is the expenditure of type  $j$  for project  $i$  in period  $k$

Subject to:

$$\sum_k X_{ijk} \leq R_{ij} \text{ for } i = 1, \dots, n \text{ and } j = 1, \dots, m \quad (3.2)$$

$$\sum_i \sum_k X_{ijk} \leq T_j \text{ for } j = 1, \dots, m \quad (3.3)$$

where,

$n$  is the number of projects

$m$  is the number of expenditure types

$R_{ij}$  is the total requested expenditure of type  $j$  for project  $i$

$T_j$  is the total available expenditure of type  $j$

$$\begin{aligned} X_{ij1} - X_{ij2} &\leq 0 \text{ for } i = 1, \dots, n \text{ and } j = 1, \dots, m \\ X_{ij2} - X_{ij3} &\leq 0 \text{ for } i = 1, \dots, n \text{ and } j = 1, \dots, m \\ X_{ij3} - X_{ij4} &\leq 0 \text{ for } i = 1, \dots, n \text{ and } j = 1, \dots, m \end{aligned} \quad (3.4)$$

Second, not only were expenditures non-increasing, but for the entire RMP, expenditures in the first year amounted to more than 35% of the total expenditures for the four years. Approximately equal budget and FTE units were expended for the subsequent three years of the plan, with greater than

15% of the total for each of those years. We relaxed these actual findings slightly to allow for more latitude in final solutions (3.5).

$$\begin{aligned} X_{ij1} & \text{ 35\% of } T_j \text{ for } j = 1, \dots, m \\ X_{ijk} & \text{ 15\% of } T_j \text{ for } j = 1, \dots, m \text{ and } k = 2, \dots, 4 \end{aligned} \quad (3.5)$$

Finally, three out of the four projects funded in the 1990 RMP were funded at a level greater than or equal to 18% of requested allocations. The exception was “anadromous fish,” which was supported at 8.9% and 5.4% for budget and FTE’s, respectively. Projects numbered 1, 2, and 3 in the following constraints (3.6) are the highest ranked projects other than avalanche forecasting. To be consistent with the most conservative allocation from the 1990 RMP, we constrained solutions by requiring that both budget and FTE allocations for each of these three projects be greater than or equal to 5.4% of requested expenditures. A constraint was added to allocate 50% of requested expenditures for “avalanche monitoring” to make our allocation reflect exogenous stipulations used in the 1990 RMP.

$$\begin{aligned} X_{ijk} & \text{ 5.4\% of } T_j \text{ for } i = 1, \dots, 3 \text{ and } j = 1, \dots, m \\ X_{[\text{Avalanche forecast}]jk} & \text{ 50\% of } T_j \text{ for } j = 1, \dots, m \end{aligned} \quad (3.6)$$

Based on the objective function (3.1) and constraints (3.2-3.6), optimal allocation of budget and FTE units was performed for the different sets of project priorities in Table 1. Results for staff-assigned priorities, for equal objective priorities, for “management decision making” as the only objective, and for the actual 1990 RMP appear in Table 2. To facilitate comparisons with 1990 RMP allocations, at least four projects under each scenario were allocated expenditures as specified in the last constraint (3.6).

## 4. RESULTS AND CONCLUSIONS

Different scenarios of importance for the objectives in the AHP model produced different project priorities and rankings (Table 1). Projects with the five highest rankings all have relatively high priority scores, while the three lowest priority projects have markedly lower scores. However, a scenario in which “management decision making” is the only objective causes a considerable shift in priorities, such that, “goat impacts” is the highest-ranked project and “anadromous fish” has moved up to third.

Results for the final scenario column, in which rankings are based on the 1990 RMP, differ from each of the previous sets of rankings. Apparently, the park's current, informal process follows a non-explicit set of objectives, which diverges from the explicit objectives of our other scenarios.

*Table 2.* Based on the LP formulation, optimal total expenditures of budget (\$ thousands) and FTE's are displayed for the four scenarios of park objectives

Project	Staff-assigned priorities	All objectives equal	Mgmt decision making	Actual 1990 RMP
Air quality				
Budget				49.6
FTE's				2.0
Avalanche				
Budget	22.00	22.00	22.00	22.00
FTE's	0.60	0.60	0.60	0.60
Water quality				
Budget		20.09		
FTE's		0.20		
Goat impacts				
Budget	6.91		97.72	55.00
FTE's	0.25		3.80	2.2
Sensitive wildlife				
Budget	34.45	34.44		
FTE's	1.33	1.32		
Anadromous fish				
Budget			9.72	16.00
FTE's			0.40	0.40
Sensitive wildlife				
Budget	34.45	34.44		
FTE's	1.33	1.32		
Anadromous fish				
Budget			9.72	16.00
FTE's			0.40	0.40
Elwha watershed				
Budget	79.24	66.04	13.16	
FTE's	3.02	3.09	0.40	
IPM program				
Budget				
FTE's				

When looking at groups of projects, one notices that four out of the five projects, "water quality," "goat impacts," "sensitive wildlife," "anadromous fish," and "Elwha watershed," are the highest ranked projects in each of the first three scenarios. Although some reordering of rankings occurs, these five projects seem to be important regardless of what explicit objectives influence park management.

The LP solutions listed in Table 2 are not unique, but they are optimal. By including more projects (an actual RMP exercise might contain hundreds) or more constraints regarding the relative expenditures between projects or the timing of those expenditures over the planning horizon, it should be possible to create a situation in which there is a unique optimal solution, or even no feasible solution. However, the presence of multiple optimal solutions should not be interpreted negatively, as it provides the park manager with additional latitude to choose a final plan and to react to annual changes in park budgets.

Similarities between priority rankings for the first two scenarios become even more apparent when we examine the allocations listed in Table 2. Except for switching expenditures on “water quality” and “goat impacts,” their allocations indicate that they are similar. This suggests that staff-assigned priorities are implementationally most similar (among these scenarios) to treating all objectives as equal. Comparison between scenarios of “staff assigned” priorities and “support management decision making” produces numerous differences. Despite similar project rankings in Table 1, these two scenarios differ substantially in their LP solution. This follows naturally, because the allocation of resources in the LP model is a function of actual priority *values*, and these values may generate very different resource management plans despite similar project *rankings*.

## 5. DISCUSSION

Most agencies currently have an established structure for developing strategic management plans, but plans are often lengthy and cumbersome, because of efforts to make them comprehensive. Tactical implementation of these plans is generally much less structured. The selection of individual project priorities is rarely quantified, and the rationale for those priorities is not documented. Allocation of limited financial and human resources is often based on criteria that are not quantified or clearly articulated. In general, considerably less effort is devoted to project prioritisation and plan implementation than to the development of the RMP itself.

In the case study conducted for Olympic NP, we found that resource managers are highly receptive to alternative approaches to evaluating a RMP. The complexity of multiple objective planning and project prioritisation was simplified by using the AHP. Furthermore, management staff felt that they could present the RMP to other park staff and the general public with greater confidence if it were based on a more analytical framework grounded in quantifiable decisions. Although this case study assessed only a few projects and objectives, there was considerable support

for integrating the AHP approach into more complex aspects of resource management planning.

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# Managing Forest Ecosystems

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Volume 3

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